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Amazonian biocultural heritage under climate change

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Abstract

Amazonia harbors one fourth of the world's plant diversity and over 300 Indigenous groups. So far, however, no study has assessed how climate change may simultaneously impact its biological and cultural heritage. To bridge this gap, we assembled a database on 5,833 utilized plant species and show that climate change will reduce more the ranges of utilized than of non-utilized species by 2070. Locally, Indigenous cultures may lose an average of 65% of their utilized plant species and 50% of their associated services from climate change. Regionally, the loss of threatened languages may result in a 41% reduction in the Amazonian knowledge pool. Overall, our results point to the strong climate vulnerability of Amazonian biocultural heritage.

Biologists call Amazonia the "Earth's lungs"—for it harbors half of the world's tropical forests. Anthropologists call it a "living library"—for the sophisticated knowledge of its Indigenous and local people. So far, however, no work has assessed how climate change may simultaneously impact Amazonia's biological and cultural heritage. On the one hand, ecologists assessing the impacts of climate change have emphasized two scales: ecosystems (i.e., forest-savannah transitions (***1***)) and organisms (e.g., animals and plants (***2, 3***)). On the other hand, social scientists have addressed the importance of Indigenous and local knowledge for climate change mitigation (***4***), but not the fate of the species that matter to people. As a result of these separate investigations, our understanding of the climate change vulnerability of Amazonia's unique biocultural heritage —of its plant species, plant services, and cultures— remains incipient (**Fig. 1**).

Fig. 1.

Linking biological and cultural heritage to study climate change impacts over time.
The figure illustrates a sand clock for a particular culture in Amazonia, containing knowledge of plant species (biological heritage, green grains) and plant services (cultural heritage, black/brown grains). In this paper, we assess to what degree the biocultural heritage in this sand clock will be eroded by climate change. In our drawings of sand clocks in **Fig. 3**, this is quantified by the volume of sand grains occupying the lower globe.

To bridge this knowledge gap, and re-focus attention to those species that matter to people, we start by assessing to what degree climate change may impact the geographic range of utilized vs. non-utilized plant species. First, we reviewed 505 references on Amazonian utilized plants and recorded information for 5,833 utilized species from 74,602 literature reports. Next, we built species distribution models (SDMs) for 4,933 utilized species (85% of the utilized species in our database) and for 4,709 non-utilized species (46% of non-utilized species). We find two significant differences regarding their current distribution ranges. First, utilized plants have larger baseline ranges than non-utilized plants (t-Welch=28.14, p=1.09e-166) (fig. S1). Second, utilized plants have centroids that significantly differ in longitude (t-Welch=-12.67, p=1.70e-36) and latitude (t-Welch=-9.02, p=2.21e-19) (fig. S2 and S3). Projecting SDMs to eight climate scenarios by the year 2070, we then compared the mean change in the geographic range between utilized vs. non-utilized species. We find that climate change will differentially impact utilized plants. While non-utilized species are predicted to expand on average by 12%, utilized species are predicted to contract by a similar amount (**Fig. 2**).

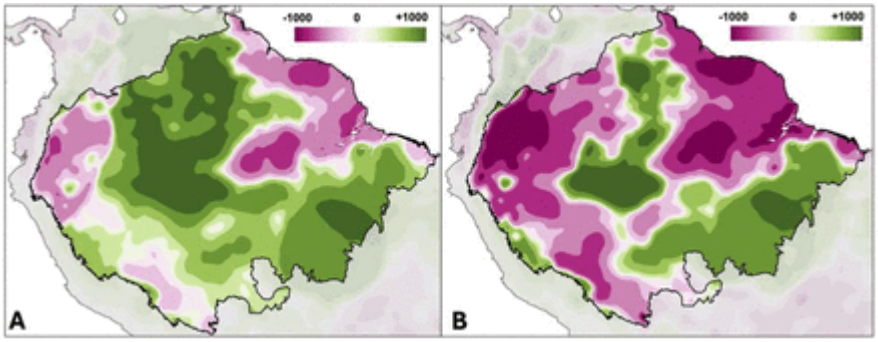

Fig. 2.

Climate change threatens biological heritage.
Change in non-utilized (**A**) and utilized (**B**) plant species richness. In both panels, colors show the median change in species richness by 2070 under an extreme climate change scenario (RCP 8.5). The consequences of climate change will be more severe for the plant species used by people.

After having assessed the regional impact of climate change on utilized species, we now examine its effects at the local scale that matters to particular Indigenous cultures. Most cultures speak a distinct language and inhabit a particular territory —which linguists have mapped as language polygons (***5***)— allowing for local scale analyses. Because many languages are under-documented, here we only focus on 78 Indigenous languages with at least ten reported useful species in the literature (range: 10 to 1279 species; mean: 148; standard deviation: 224). For each language, we built an Indigenous knowledge network (***6***) to relate individual plant species (nodes in one set) to particular services (nodes on the other set) based on the knowledge (links) held by speakers of that language (see Materials and methods). Next, we quantified the climate change exposure of each Indigenous knowledge network by calculating the proportion of utilized species and services that may be driven locally extinct by 2070. We find that, on average, the proportion of plant species and services going locally extinct is 65% (range: 0 to 100%; sd: 22%) and 50% (range: 0 to 100%; sd: 1%), respectively (**Fig. 3**). The proportion of plant services lost will vary among cultures, even for cultures losing a similar fraction of species. Such loss is uncorrelated to the geographic longitude of languages, indicating that the biocultural impacts of climate change will be felt across the entire Amazon basin. The predicted climate change impacts are also decoupled from language threat, suggesting that when planning climate change mitigation actions in Amazonia, all cultures (not only the most endangered ones) need to be considered.

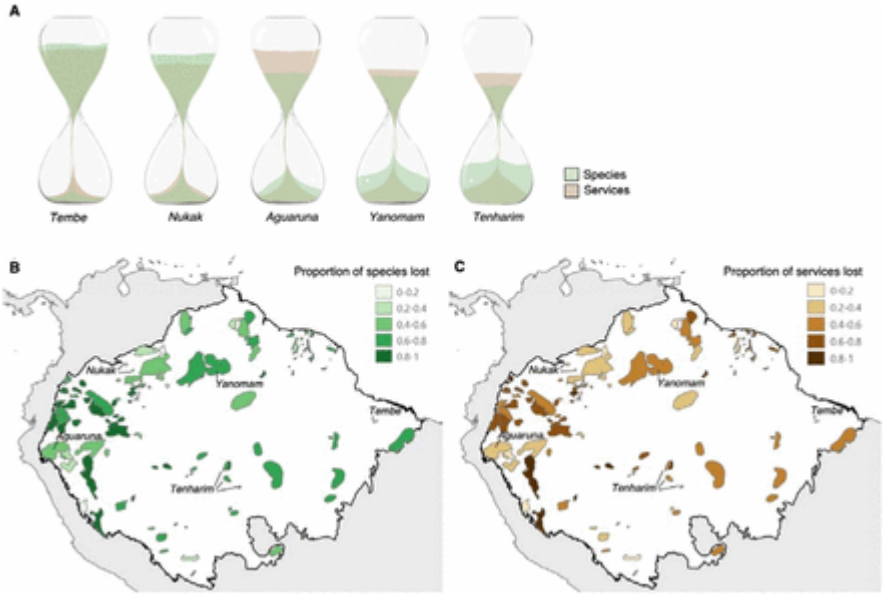

Fig. 3.

Climate change threatens cultural heritage.
(**A**) Sand clocks show the predicted local extinction of plant services due to the local extinction of plant species from climate change. Five examples are shown to illustrate that local extinction of plant species and services varies across cultures. Proportion of plant species (**B**) or plant services (**C**) that are predicted to be lost within 78 Amazonian language polygons due to climate change by the year 2070.

So far, we have focused on the biocultural loss triggered by the extinction of plants, but the extinction of culture also matters. Indeed, cultural loss may undermine Indigenous knowledge networks at least as fast as biological loss (***6***). Specifically, language extinction may trigger the loss of medicinal knowledge, as most knowledge is unique to a single language (***7***). To assess how language extinction may impact Amazonian knowledge, we first build what we refer to as the indigenous knowledge metaweb (***6***) (i.e., the total knowledge about the services provided by all plant species in the study area). We then obtained linguistic threat data for all the languages in our sample from Ethnologue —the most comprehensive catalogue of the world's languages (***5***)— and estimated the impact of language loss on the erosion of the Indigenous knowledge metaweb. From the 74,602 literature reports, 56% are from 138 Indigenous languages, of which 51% are threatened. By contrast, the other 44% are reports from non-specified languages whose threat status is unknown (81% of the 44%) or from non-Indigenous languages (e.g., Portuguese: 12%; Spanish: 7%). Accordingly, if threatened Indigenous languages vanish by the end of the century as predicted by linguists (***5***), the Amazonian metaweb would shrink by 44%. And yet, this estimate is conservative for two reasons. First, our sample includes nearly one third of Amazonian languages. Because 97% of non-sampled cultures speak threatened languages, including these in the analyses would further shrink the metaweb. Second, we (conservatively) classified all reports from non-specified languages as not threatened, but most Amazonian languages are, indeed, threatened. That is, if we would include non-specified language reports (assuming they are from threatened languages) the metaweb would shrink by 83%.

Here, we have shown that Amazonian peoples utilize at least 5,800 plant species, that utilized species may follow different climate change trajectories than non-utilized species, and that 60% of utilized

species and 50% of their associated services may become locally extinct by 2070. Our findings are a conservative best-case scenario, as we do not consider land use change or mining, two major threats to Amazonia's biocultural heritage (***8***). Hundreds of cultures and their languages have disappeared due to post-contact disease, epidemics, slavery and violence (***9***). As a result, their knowledge on the use and management of the world's most biodiverse forest has been forever lost. Today, if languages continue to erode, much of the recorded knowledge will not be passed to the next generation, limiting the future wellbeing of the region's inhabitants. Our results strongly hint to the possibility that the climate tipping point for Amazonia (***10***) will not only impact ecosystem and biological diversity, but also cascade across the biome's astonishing and unique cultural heritage.

Supporting information

Supplementary Material | [supplements/617268_file03.docx]

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Competing interests

Authors declare that they have no competing interests.

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